Lecture Module - Steady State Circuits

ME3023 - Measurements in Mechanical Systems

Mechanical Engineering

Tennessee Technological University

Topic 4 - Steady State Circuits

Module 4 - Steady State Circuits

- Topic 1 - Components, Units, and Symbols
- Topic 2 - Fundamental Laws
- Topic 3 - Circuit Applications

Topic 1 - Components, Units, and Symbols

- Passive Components
- Electrical Quantities
- Units and Symbols
- Types of Switches

Passive Components

Passive components affect the behavior of a circuit in different ways but they do not generate power and can only absorb energy or transform it into heat. Active components on the other hand...

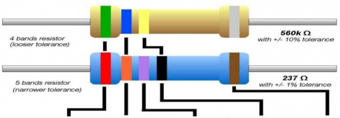
- Resistor
- Capacitor
- Inductor

Most circuits require an active power source for operation. A voltage source is used in most applications however current sources are also available and are needed for specialized electrical applications.

Passive Components

Components are identified by color codes and numbering systems. However it is always a good idea to measure for yourself because a marking can be incorrect or a component may be damaged.

Resistor Color Code



Color	1st Band	2nd Band	3rd Band	Multiplier	Tolerance
Black	0	0	0	x 1 Ω	
Brown	1	1	1	x 10 Ω	+/- 1%
Red	2	2	2	x 100 Ω	+/- 2%
Orange	3	3	3	x 1K Ω	
Yellow	4	4	4	x 10K Ω	
Green	5	5	5	x 100K Ω	+/- .5%
Blue	6	6	6	x 1M Ω	+/- .25%
Violet	7	7	7	x 10M Ω	+/- .1%
Grey	8	8	8		+/- .05%
White	9	9	9		
Gold				x .1 Ω	+/- 5%
Silver				x .01 Ω	+/- 10%

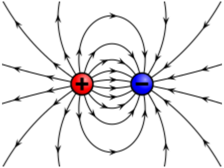
Codes of Ceramic Disc Capacitor

www.circuitspedia.com

Picofarad pF	Nanofarad nF	Microfarad µF	CODE	Picofarad pF	Nanofarad nF	Microfarad µF	CODE
10	0.01	0.00001	100	4700	4.7	0.0047	472
15	0.015	0.000015	150	5000	5.0	0.005	502
22	0.022	0.000022	220	5600	5.6	0.056	562
33	0.033	0.000033	330	6800	6.8	0.0068	682
47	0.047	0.000047	470	10000	10	0.01	103
100	0.1	0.0001	101	15000	15	0.015	153
120	0.12	0.00012	121	22000	22	0.022	223
130	0.13	0.00013	131	33000	33	0.033	333
150	0.15	0.00015	151	47000	47	0.047	473
180	0.18	0.00018	181	68000	68	0.068	683
220	0.22	0.00022	221	100000	100	0.1	104
330	0.33	0.00033	331	150000	150	0.15	154
470	0.47	0.00047	471	200000	200	0.2	254
560	0.56	0.00056	561	220000	220	0.22	224
680	0.68	0.00068	681	330000	330	0.33	334
750	0.75	0.00075	751	470000	470	0.47	474
820	0.82	0.00082	821	680000	680	0.68	684
1000	1.0	0.001	102	1000000	1000	1.0	105
1500	1.5	0.0015	152	1500000	1500	1.5	155
2000	2.0	0.002	202	2000000	2000	2.0	205
2200	2.2	0.0022	222	2200000	2200	2.2	225
3300	3.3	0.0033	332	3300000	3300	3.3	335

Electrical Quantities

- Charge - the physical property of matter that causes it to experience a force when placed in an electromagnetic field.



- Voltage - the difference in electric potential between two points ... can be caused by electric charge, by electric current through a magnetic field, by time-varying magnetic fields, or some combination of these three.
- Current - the rate of flow of electric charge past a point or region. An electric current is said to exist when there is a net flow of electric charge through a region.

Electrical Quantities

- Resistance - a measure of a components opposition to the flow of electric current. The inverse quantity is electrical conductance, and is the ease with which an electric current passes.
- Capacitance - the ratio of the change in electric charge of a system to the corresponding change in its electric potential (voltage).
- Inductance - the tendency of an electrical conductor to oppose a change in the electric current flowing through it. The flow of electric current creates a magnetic field around the conductor. The field strength depends on the magnitude of the current, and follows any changes in current.

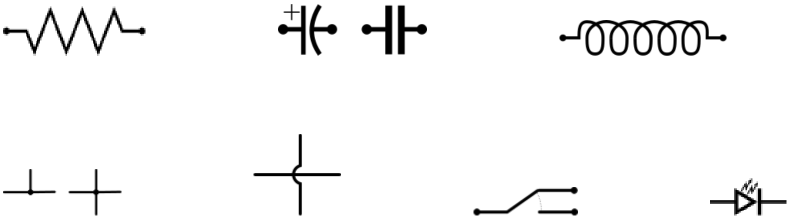
Units and Symbols

Quantity	Symbol	Unit	Abbr.
Charge	Q,q	Coulomb	C
Voltage	V,v	Volt	v
Current	I,i	Ampere	A
Resistance	R	Ohm	Ω
Capacitance	C	Farad	F
Inductance	L	Henry	H

Question: When should you use upper case or lower case letters for electrical quantities?

Units and Symbols

When working with a or building a circuit you need a diagram. Draw or find one before you begin. Here are some commonly used symbols.



Types of Switches

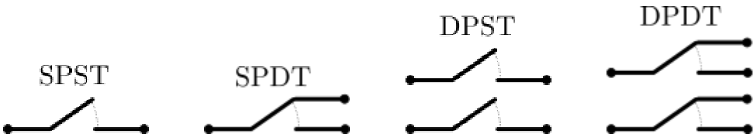
A switch is a mechanical-electrical device that that can change from a continuous state to a dis-continuous state and they are used as a mechanical interface to a circuit. There many different types of switches for different purposes and this is not an exhaustive list.

- Toggle Switches
- Momentary Switches
- Reed Switches
- Level or Float Switches
- and many more

Types of Switches

Toggle switches are are possibly the most commonly used switches and they come in many different forms.

Poles - The numbers of poles refers to the number of independent conductors or circuits in a switch that are controlled by the same toggle or input.
Throws - The numbers of throws refers to the number of output terminals of a switch per pole.



Topic 2 - Fundamental Laws

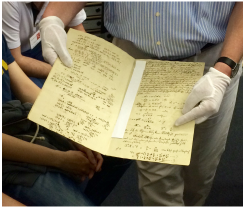
- Ohm's Law
- Combining Resistance
- Kirchhoff's Laws
- Power Dissipation

Ohm's Law

James Maxwell

George Ohm

Ohm's Notebook

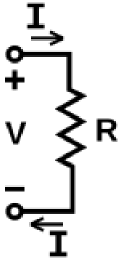


Ohm did his work on resistance in the years 1825 and 1826, and published his results in 1827 as the book Die galvanische Kette, mathematisch bearbeitet...

Ohm's Law

Ohm's law states that the current through a conductor between two points is directly proportional to the voltage across the two points.

$$I = \frac{V}{R}$$

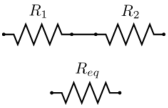


It is more commonly shown in the following form.

$$V = IR$$

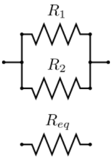
Combining Resistance

Resistors in Series



$$R_{eq} = R_1 + R_2$$

Resistors in Parallel



$$R_{eq} = \frac{1}{\frac{1}{R_1} + \frac{1}{R_2}}$$

Kirchhoff's Laws

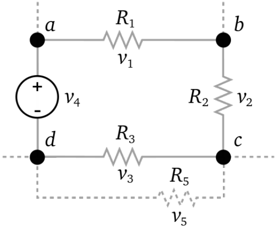
Both of Kirchhoff's laws can be understood as corollaries of Maxwell's equations in the low-frequency limit. They are accurate for DC circuits, and for AC circuits at frequencies where the wavelengths of electromagnetic radiation are very large compared to the circuits.

1. Kichhoff's Voltage Law (KVL)
2. Kichhoff's Current Law (KCL)

Kirchhoff's Laws

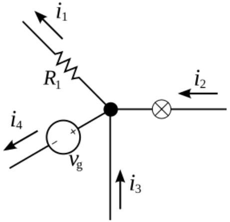
Kichhoff's Voltage Law (KVL) - The sum of the voltages around a loop (aka mesh) equals zero.

$$\sum_{k=1}^{n} v_k = 0$$



Kichhoff's Current Law (KCL) - The sum of the current flowing in and out of node (aka junction) equals zero.

$$\sum_{k=1}^{n} i_k = 0$$



Kirchhoff's Laws

Power Dissipation

Energy is transformed in to heat in passive circuit components. For a resistor the power dissipation can be found with following relations.

$$P = IV \qquad\qquad V = IR$$

Power Dissipation

Power is the rate of energy dissipated, aka the amount of energy lost per unit of time. How do we compute total energy for the power?

$$E = \int_{t1}^{t2} P dt$$

Topic 3 - Circuit Applications

- Circuits in Mechanical Engineering
- Drain Pipe Theory
- Example 1: LED Circuit
- Example 2: LDR circuit

Circuits in Mechanical Engineering

How much does a mechanical engineer need to know about electricity and magnetism? This is good question, and obviously it varies based on your particular area of mechanical engineering. However...

- System design is integrated! Look around you, can you find anything that was developed or designed without circuits? Engineering is an integrated discipline and very few products or designs are isolated so to a single field.
- Further, the need for measurements in mechanical systems drives the need for a mechanical engineer to have a solid foundation in basic circuits theory.

Circuits in Mechanical Engineering

Mechatronics
Many devices or designs combine mechanical and electrical systems. This is known as Mechatronics and if you are interested in this area you are in a great place to learn. TnTech Mechanical Engineering offers a concentration in Mechatronics Engineering. In this degree you will study both mechanical engineering and electrical engineering topic to give you the foundation to design truly integrated systems! Ask me or Dr. Canfield if you have any questions about this.

Drain Pipe Theory

Fluid Flow - Hydraulic Analogy

Traditionally engineers have used an analogy relating the movement of electrons to the flow of water through a pipe (hydraulic analogy) known as *drain-pipe theory*.

This may provide a sense of intuition *however* this comparison is not accurate do to the non-Newtonian nature of electricity and magnetism (more on this). It can be used to visualize some basic circuits principles, but it should not be used for analysis of complex electrical systems.

Example 1: LED Circuit

LEDs or Light Emitting Diodes are used more and more everyday and traditional *incandescent* lights are used rarely in new deigns. Why are LEDs better? Can you think of any trade-offs?

Pros:

-
-
-

Cons:

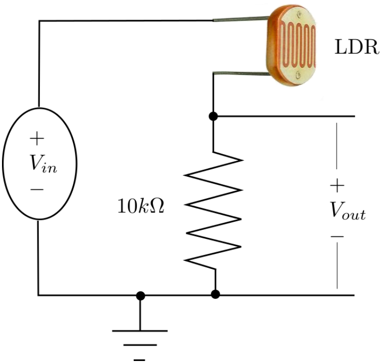
-
-
-

Example 1: LED Circuit

Design a circuit with a voltage source, an LED, a resistor, and a SPST switch for turning on the LED. Choose the resistor such that the current is in the appropriate for a typical LED ($\sim 20mA$). The voltage drop for a green LED at $\sim 20mA$ in known to be $\sim 3.5v$.

Example 2: LDR circuit

Consider this circuit for measuring light intensity with an LDR (light dependent resistor). The sensors is used in a voltage divider circuit.



1. Find the current in the circuit.
2. Find the voltage across the LDR and the $10K\Omega$ resistor.
3. Find the total energy dissipated in the circuit over 60 seconds.
4. Question: Why is the $10K\Omega$ resistor needed?

Example 2: LDR circuit

Space to work